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Concept Analysis Tools

Evaluation of Available Concept Analysis Tools for Military Design

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This research investigated methods of automating the conceptual design stages of a project while enhancing the use of CAD. Researchers evaluated four commercial software packages and three CAD development platforms to see if they could be customized to meet Army needs.

MicroStation PC Version 4.0, MicroStation Development Language (MDL), and Oracle's Relational Database Management System (RDBMS) together are an excellent platform for automating the conceptual design stages of a project. Intergraph products and their MicroStation CAD engine are used extensively in the Corps of Engineers. MDL allows complete user customization, and the RDBMS provides the ability to associate graphic and nongraphic information in a shared environment.

It is recommended that research be continued to develop automated tools using the MicroStation 4.0 platform. The tools, including building code examinations, quantity takeoffs, inventory, and space and personnel allocation, should be pilot-tested at districts and divisions.

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Most Computer-Aided Design (CAD) software is written to be used as a drafting tool for the early design phase are not available within CAD systems. Army districts, divisions, and architect/engineers need a single automation package that contains tools for architectural design, conceptualization, drafting, facility planning, and facility management.

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FOREWORD

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This research was performed by the Architectural Design and Management Team, Facility Systems Division (FS), U.S. Army Construction Engineering Research Laboratory (USACERL). In addition to the authors, USACERL personnel directly involved in the study were Jeffery S. Heckel and Steven Daniel Foutch. Mr. L. Michael Golish is the Team Leader of the Architectural Design and Management Team and Dr. Michael J. O'Connor is Chief of USACERL-FS. The technical editor was Gloria J. Wienke, USACERL Information Management Office.

COL Daniel Waldo, Jr. is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

Computers and Computer-Aided Design (CAD) software are becoming necessary tools not only for architectural drafting, but also for concept design, facilities planning, and facilities management. Most CAD software is written to be used as a drafting tool only; tools for the early design phase are not available within CAD systems. Software packages that include concept design, facilities planning, and facilities management must be purchased separately. U.S. Army Corps of Engineers (USACE) districts, divisions, and architect/engineers (A/Es) need a single automation package that contains tools for architectural design, conceptualization, drafting, facility planning, and facility management.

In an effort to fulfill this need, the Directorate of Military Programs, Headquarters, U.S. Army Corps of Engineers (HQUSACE) tasked the U.S. Army Construction Engineering Research Laboratory (USACERL) with evaluating available commercial and in-house packages that would combine conceptual design with CAD capabilities and would allow nongraphic data manipulation.

Objective

The overall objective of this research is to develop methods of automating the conceptual design stages of a project while enhancing the use of CAD before and after construction. These methods must operate in a personal computer (PC) environment, be compatible with the Corps of Engineers' dominant CAD system (Intergraph), and be able to manipulate nongraphic information by connecting to a shared database management system (DBMS).

The focus of this phase of research was to evaluate available commercial and in-house packages to determine if they could be used to meet the overall automation objective.

Approach

Researchers evaluated four commercial software packages written solely for facility planning, facility management, and conceptual design. These packages are the most prevalent on the market. Three packages were too simple. The fourth was a stand alone package that separated conceptual design, drafting, and facility planning from the architectural design process. None of these packages met the objective.

In an attempt to find other solutions, USACERL researchers evaluated two commercial (AutoCAD with CAD/Base and Advanced Relation, and MicroStation 3.3 with dBase III Plus) and one in-house (Design 4D) CAD development platforms to see if they could be customized to meet Army needs. The requirements for platforms are: a CAD engine, a shared DBMS, and an application development environment. At the time of the evaluation, none of these platforms was sophisticated enough to meet the Army's conceptual design needs. However, Bentley Systems Inc. was developing a new release of their MicroStation platform; it showed potential. Since this new release was still under development, a contract was initiated between the company and USACERL to beta test MicroStation PC Version 4.0. The beta test lasted for 8 months.

Mode of Technology Transfer

It is recommended that pilot program concept analysis tools be sent to various USACE districts for testing. When all changes have been made and research is concluded, it is also recommended that the concept analysis tools and user's manual be distributed to USACE districts and divisions equipped with MicroStation 4.0 and Oracle Database Tools. The information collected from user feedback will be used for future development

of similar programs, and for a study of the effect of CAD on design, facility planning, and facility management.

2 CONCEPT ANALYSIS TOOLS EVALUATED

Thumbnail 3D

Thumbnail 3D (Version 1.0) was written for creative architectural designers who do not need to learn AutoCAD in detail. Thumbnail 3D requires AutoCAD Release 10 (DOS or 386 Version) or Release 11. For good performance, the optimal configuration should consist of a 386 central processing unit (CPU) running at 25 MHz, with 6 megabytes of expanded memory. Thumbnail 3D is written by Integrated Computer Graphics, a trademark of ICG Acquisition Corporation, Santa Ana, CA.

Thumbnail 3D was created to simplify preliminary visualization, conceptual design, and drafting. The package provides modules for the preliminary design stages such as bubble, block, and space diagrams. After the user has designed the space diagrams, the program generates a single line floor plan. Wall thickness, windows, doors, wall heights, and roofs can then be added to the floor plan. The end result is a three-dimensional (3D) object with a roof, doors, and windows.

Thumbnail 3D also allows takeoff functions. It produces separate reports denoting the areas of specific spaces, wall surfaces, and roofs. Other reports contain quantity takeoffs and information concerning the length (in units specified by the user) of the interior and exterior walls. Detailed reports are not an option and the system has no cost reporting capabilities.

As a conceptual design tool, Thumbnail 3D is not quite complete. It is weak in reporting functions and data entry. It does not have any adjacency capabilities. Thumbnail's strengths are in the 3D drawing and viewing capabilities.

Data entry is inefficient because there are no data entry screens. Data for a space is defined at the same time it is drawn. To change any of the information attached to a space, the space must be deleted and redrawn with the new information. Compared to other packages, this is the slowest and most inefficient way to enter space information.

Other drawbacks of Thumbnail 3D are file transferring, speed, and software requirements. Graphic files can be transferred out of Thumbnail 3D through DXF format, but all attached text attributes are lost. Thumbnail 3D is a very slow program. During evaluation, it took more than 30 minutes to load on a 20 MHz, Compaq 386 machine with 9 megabytes expanded memory. Although the test computer runs slower than the optimal computer, a 30-minute wait is excessive. The wait time did not include the time it took for floor plans to generate or separate commands to load. Also, since AutoCAD is required, it would seem more sensible if a better relationship existed between Thumbnail 3D and AutoCAD.

Spacetek

Spacetek is a strategic facility planning package developed for facility managers, planners, consultants, and architects. It provides a framework for evaluating property and facility needs. The software requires Version 2.1 (or higher) of Microsoft Windows/286, a 286 CPU, 1 megabyte of extended memory, and 20 megabytes of hard disk space. Spacetek was written by Dover Technologies Pty Limited, Sydney, Australia.

Spacetek is both a space planning and facility management tool. This program provides a multiuser interface through a local area network, as well as methods for producing organizational charts, affinity diagrams, stack diagrams, and block plans. Spacetek allows forecasting of organizational needs for distinct time periods.

This program supports a commercial standard query language (SQL) package relational database (SQLBase) that stores the text attributes for the

graphic functional layouts. Space and circulation tables organized in a Microsoft windows format are the primary form of data entry. This database has a user friendly data entry interface. Because of the SQL interface, the user can customize reports. SQLBase is an essential part of Spacetek as it combines PC user interfaces with large system database management.

Affinity diagrams, much like functional adjacency diagrams, are also available in Spacetek. Affinities are designed to allow the user to designate which areas need to be next to each other. To use the affinity feature, the user must assign an affinity factor to each space while entering the data. When the bubble or block diagrams are generated, the affinity values are considered and the elements are placed accordingly. If no values are specified, the elements are displayed randomly.

Spacetek is a very thorough facility management and space planning software system. The graphical interface that generates floor plans and stack diagrams is impressive. Data entry through database windows is efficient and user friendly. The only problems with Spacetek are the adjacency form, the lack of 3D viewing and drawing, and the space planning feature.

The adjacency form is a large triangle matrix divided into small diamonds for data entry. When a diagram is full, it is difficult to read. Spacetek's space planning capabilities do not occur directly in the conceptual design phase. The program requires an exterior perimeter in which to place all of the interior spaces. Drawing this perimeter requires some thought about the gross square footage and form of the building. This boundary does not allow the freedom of placing bubbles or blocks, adjusting them, and then defining the floor plan.

This program does not allow the transfer of database information to a CAD system. When graphic files are transferred, all previously attached database attributes are lost.

CAFM-SPACE

CAFM-SPACE (Version 4.0) is used as a decision support tool for facility managers. It features analysis, planning, and tracking tools that integrate a company's property, building data, organizational data, and facility graphics data. Minimum hardware requirements are an IBM AT, 640K memory, 20 megabyte hard disk, VGA monitor, and mouse. CAFM-SPACE does not require a resident CAD package. This software was written by CAFM-WORKS INC. of Cambridge, MA.

Designers and managers can use CAFM-SPACE to produce optimal floor plans and building designs for companies, groups, or activities. Functions such as forecasting, reporting, file transferring, and adjacencies are all possible with CAFM-SPACE.

A master database divided into two parts, property and organization, stores the project information. Graphic outputs include vertical cross sections and floor plans. Data can be viewed in a present time frame or can be forecast for a future time period. Reports can be generated in many formats including text, graphic, and DXF files. Reports are available in each of the six modules: property database, building database, organizational database, facility analysis, stack analysis, and block analysis.

Transferring graphic files to other software systems is possible through DXF file formats. Once graphic files are transferred; however, they lose all database attributes that were previously attached.

CAFM-SPACE is another facility management software system having only a few problems. Minor problems occur with graphics, adjacencies, and file transfers. A major problem with CAFM-SPACE is that it does not have 3D capabilities. Graphics are difficult to understand. The graphics are not displayed in any architectural format and are hard to read. Adjacency diagrams are possible, but only certain spaces are allowed to be factored in.

File transferring is yet another problem. Further development on bubble diagrams must take place in another CAD system. This means that in file transferring, all database attributes are lost.

ARCHIBUS/FM 5.0

ARCHIBUS is a facility management software program that includes furniture and equipment management, as well as space and design tools. This package requires AutoCAD Release 11 to be resident. Release 11 of AutoCAD must have at least a 386 processor, a 387 floating point coprocessor, at least 2 megabytes of RAM, 11.2 megabytes of free hard disk space, and PC-DOS Version 3.1 or higher. ARCHIBUS/FM 5.0 was developed by Jung/Brannen Research and Development Company, Boston, MA.

ARCHIBUS/FM 5.0 is a facility management and space planning system that uses both a database and AutoCAD 11. This system is divided into three applications: space management, design, and furniture and equipment. These three modules are complemented with an online help and can be fully customized to any user's needs.

A relational database is used to store all of the building and space information. As the data is entered, it is divided into structures that resemble the user-defined space hierarchies. This database also allows several facility operations, which are used to record the amount of linkages between one or more elements. Since this database holds a special file for each type of data, no data will be repeated.

The space management module has four main tasks: inventory, forecasting, allocation, and layout. These four tasks enable the user to generate a block or bubble diagram, forecast for five time periods, and track building information by "clicking" on the graphic location of the element.

The design module is used to generate drawings in the design development phase. This module includes drawing management, schedules, and conversions to and from 3D drawings. Since this package runs in AutoCAD, the commands and menus mimic those used in AutoCAD Release 11. This module also includes commands for drawing walls, windows, ceiling grids, and doors.

The furniture and equipment module is used to manage facility needs. This module is divided into four disciplines: furniture specifications, furniture inventory by counts, tagged furniture inventory, and equipment inventory.

ARCHIBUS/FM 5.0 is a very complete computer aided facility management software package. Because the package runs within AutoCAD Release 11, the problem of losing database linkages while transferring files is resolved. However, because the database used is not stand alone, the intelligence cannot be used in other CAD systems. This causes a problem since most of the Corps districts and divisions use Intergraph products. Transferring of database intelligence between AutoCAD and Intergraph would again result in lost information.

Summary

All of the commercial software packages evaluated addressed specific needs of facility planners, managers, and architects. However, none of these packages allowed the database intelligence linked to graphical elements to be preserved from the initial facility planning/concept design stage to the construction and facility management stage. This progression was believed to be one of the most important aspects of interpreting the design and facility management process. Therefore, further evaluation of development platforms was required.

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3 DEVELOPMENT PLATFORMS EVALUATED

Design 4D

The Design 4D (3D modeler plus database) prototype was developed at USACERL to allow architectural designers to create 3D drawings during conceptual design. Design 4D's minimum configuration consists of a 640K, 286 CPU-based machine with math coprocessor. If additional memory is provided, performance increases. The program is written in the "C" language. Design 4D contains its own database, including object oriented capabilities.

Design 4D's most impressive capability is its 3D interface. This interface allows the user to sketch in perspective by working on a drawing plane that imitates a two-dimensional (2D) drawing surface. The designer could use 2D experience to create 3D mass models. The perspective drawing could then be rotated, manipulated, and rendered making it simpler to view and make design decisions. This 3D interface was incorporated in Release 3.0 of Cadvance, a PC-based CAD system marketed by Isicad, Inc., Anaheim, CA.

After an object (or a set of lines) was placed in a Design 4D drawing file, it could be placed in an object library and given textual attributes. These objects could be saved in a library and retrieved later in another project.

Design 4D's database was developed for 3D object modeling. The ability to factor relationships between spaces is slow and will require further development. Also, the system does not contain drafting tools. The lack of a drafting system results in database information being lost due to interface problems.

AutoCAD, CAD/Base, Advanced Revelation

AutoCAD Releases 10, 11, and 386, written by Autodesk Inc., can be combined with CAD/Base and Advanced Revelation to produce a complete applications development environment. AutoCAD provides the standard CAD engine. CAD/Base, written by The van der Roest Group, links CAD drawings to a relational database. It allows window creation, menu building, query and report generation, compiling, debugging, and DXF translations. Advanced Revelation is a package produced by Revelation Technologies, Inc., and includes the relational database, R/Basic (the programming language), and a full-screen editor. It provides other tools such as Paint, for data entry window generation; Popup, for general information display; Menus; RList, a query language; Macros; and The Command Level (TCL), a data entry window for system commands. Combining these three systems provides all the tools needed to customize applications, like space planning and facility management, for AutoCAD. The minimum hardware requirements are an IBM compatible computer with 4 megabytes RAM, and a 20 megabyte hard disk.

The price of Advanced Revelation is high compared to other development environments. Also, Advanced Revelation demands a large amount of disk space to operate. These conditions do not satisfy the research qualifications as stated in the objective.

MicroStation 3.3 and dBase III Plus

MicroStation 3.3, a PC CAD engine by Bentley Systems Inc., was written to be compatible with Intergraph's VAX-based Interactive Graphics Design Software (IGDS). It provides an interface to Ashton Tate's dBase III Plus database package. It can be customized by implementing User Commands (UCM) to automate user input, test and loop for expected conditions, perform limited arithmetic operations, and simulate operator input. The high-level language application, called MicroStation Customer Support Library (MicroCSL), uses a standard "C" compiler such as Microsoft Version 5.1. This language allows single tasking applications to be implemented from within MicroStation. Using UCMs, a programmer can call a MicroCSL program to perform complicated arithmetic, element placement, and MS-DOS operations. MicroStation 3.3 requires an IBM PC/XT, PC/AT, or PS/2, or any other compatible PC with PC-DOS 3.0 or higher.

The dBase III Plus database interface allows elements in the design file to be linked to relational database records. dBase III has some query and programming capabilities using forms, but the majority of user input must come from tutorial screens, which are created from within MicroStation.

The ability to write and produce user-defined menus is also available in MicroStation 3.3. MicroStation has a large selection of menus, all of which can be defined by the user. Paper and screen menus can be written to guide a user through a series of user commands or programs.

MicroStation PC 3.3 has a powerful CAD engine, but has a very unfriendly user interface. Although the UCMs attempt to make MicroStation PC 3.3 user programmable, they have many limitations. A very small set of variables limits UCMs to simple user commands and arithmetic calculations. The MicroCSL interface has more abilities than the UCMs, but when a MicroCSL program is implemented, there can be no interaction between MicroStation PC and the program. The lack of interaction between UCMs, MicroCSL, and MicroStation is the major obstacle to using this platform for further research.

The ability to link to a commercial database is a major plus for MicroStation PC. dBase III, however, is not a strong database. dBase III does not support the full SQL, and minimal operations within dBase's data entry forms limit the sophistication of user input interfaces.

MicroStation PC 4.0 and Oracle Tools

MicroStation PC 4.0, released in March 1991, has the same CAD engine as previous versions but also has an enhanced graphical user interface (GUI), application development language, and database linkage that creates a system with great potential. The active database, Oracle, uses SQL as the database programming tool. Additional programs can be written for MicroStation using MicroStation Development Language (MDL) combined with "C" code. MicroStation 4.0 requires at least 2 megabytes of RAM, and a 40 megabyte hard drive. It was developed by Bentley Systems Inc., an affiliate of the Intergraph Corporation.

Except for the basic CAD engine, MicroStation 4.0 is virtually a new product from the 3.5 version. One of the most noticeable new features is the GUI, which displays movable and resizable views, tool palettes, pull-down menus, and dialog and setting boxes. This feature makes the platform very easy to use.

Along with the old UCMs and MicroCSL, MicroStation 4.0 now provides MDL. MDL is a complete development environment that lets applications take full advantage of the power of the MicroStation CAD engine. MDL is used to customize MicroStation with the ability to create dialog boxes, pull-down menus, palette menus, and to manipulate the database. To the user, an MDL application cannot be distinguished from a core MicroStation application. MDL is also easy to port from one MicroStation platform to another (Unix, Macintosh, DOS), so that applications that run on a PC can also run on Intergraph workstations.

The most sophisticated new tool, by far, is the interface with the commercial product Oracle RDBMS. This interface allows the association between nongraphical data and graphical drawings. MicroStation and Oracle support this database across all of the MicroStation hardware platforms including the Apple, Intergraph Workstations, and PC. Linking with a commercial RDBMS that is supported on all of the desired platforms is one of the most important updates from the previous versions and is essential to the development of conceptual design tools.

Summary

MicroStation Version 4.0 was the most integrated and comprehensive of the development platforms evaluated. Therefore, researchers decided to investigate this platform further by developing one of the Concept Analysis Tools, Functional Layout/Analysis, using MicroStation 4.0, MDL, and Oracle RDBMS.

4 RESEARCH IMPLEMENTATION

Developing the Functional Layout/Analysis in MicroStation PC 4.0 required training in the Oracle RDBMS and the MDL interface. Once the Oracle training was complete, researchers were able to implement the first component, the Oracle SQLForm, which allows the architect or designer to input building information such as square footage, project name, division, zone, section, and adjacency factors (Figure 1). This information is entered through either an Oracle SQLForm independently or from within MicroStation.

Once the form is completed, blocks and/or bubbles are generated in the MicroStation drawing file using MDL. Three-dimensional blocks are generated if the user has specified a floor elevation and height. The blocks are generated according to the functional adjacency factors by using an external "C" language algorithm and MDL. If adjacency factors have not been specified, the user can select, using the Functional Layout Window (Figure 2), whether to place the largest space first, then encircle it with the other spaces (Figure 3), or place them in a straight line.

While remaining linked to the Oracle database information, the designer can dynamically move the blocks and/or bubbles around, designing different conceptual layouts. The designer can change the location, square footage, and other attributes, either through the database or graphically, and the building information will automatically update.

After an acceptable space layout is developed, the drawing can be edited and enhanced using MicroStation 4.0. Multilines, representing walls, can then replace the single line block diagrams. At any time the designer can request a review of a block's database information (Figure 4) by selecting the element graphically. Every component of the Functional Layout/Analysis is integrated with MicroStation 4.0; therefore, the layout can be carried through to the construction document or facility management stage.

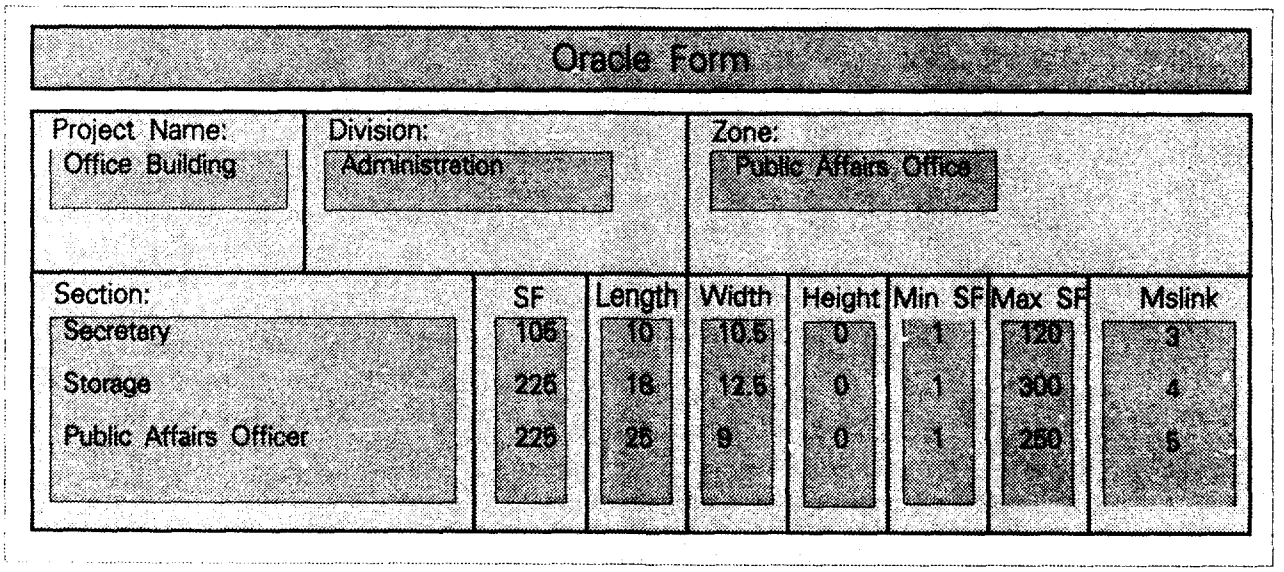

Figure 1. The Oracle SQLForm.

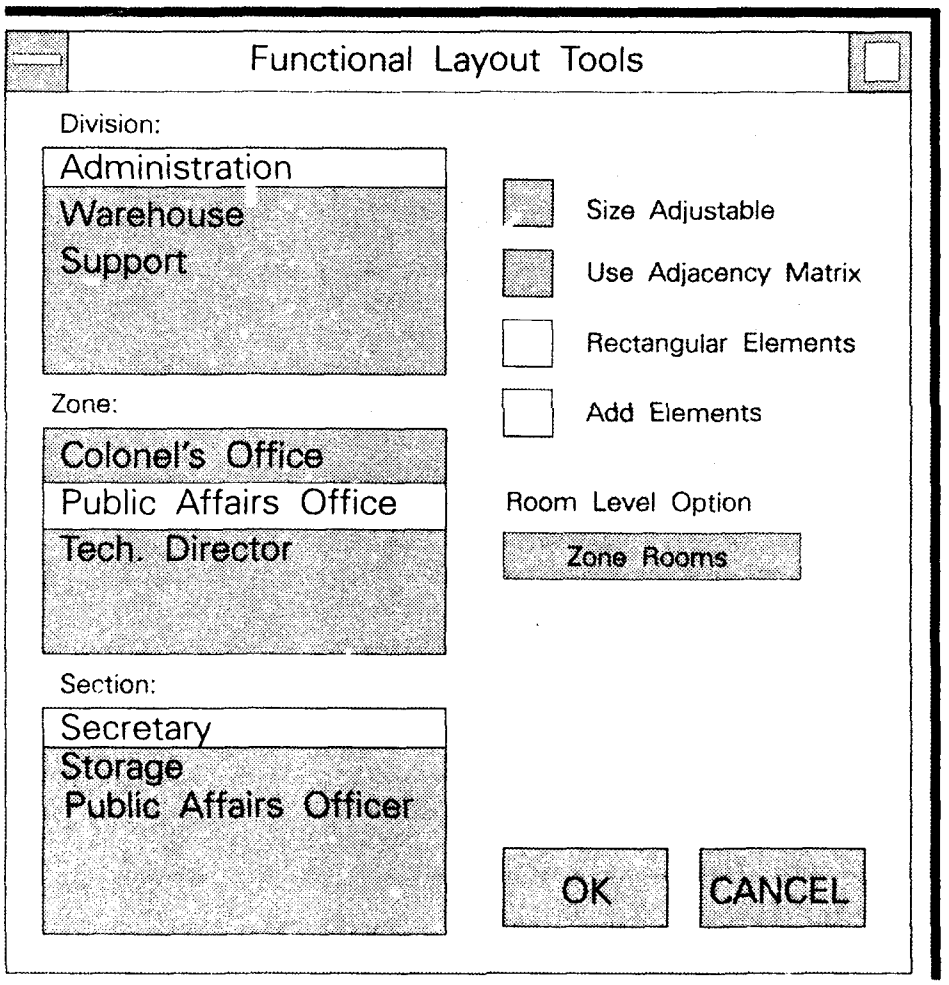

Figure 2. Functional Layout Window.

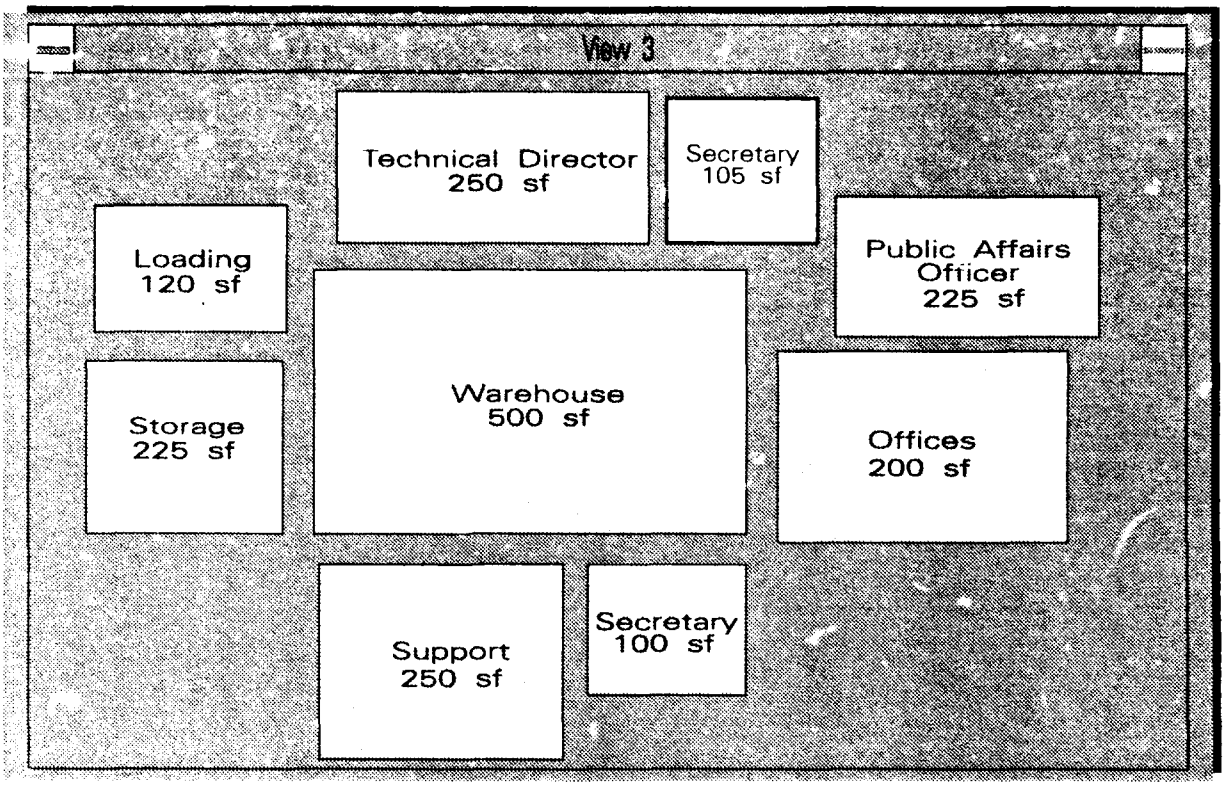

Figure 3. Layout of Adjacency Based on Size.

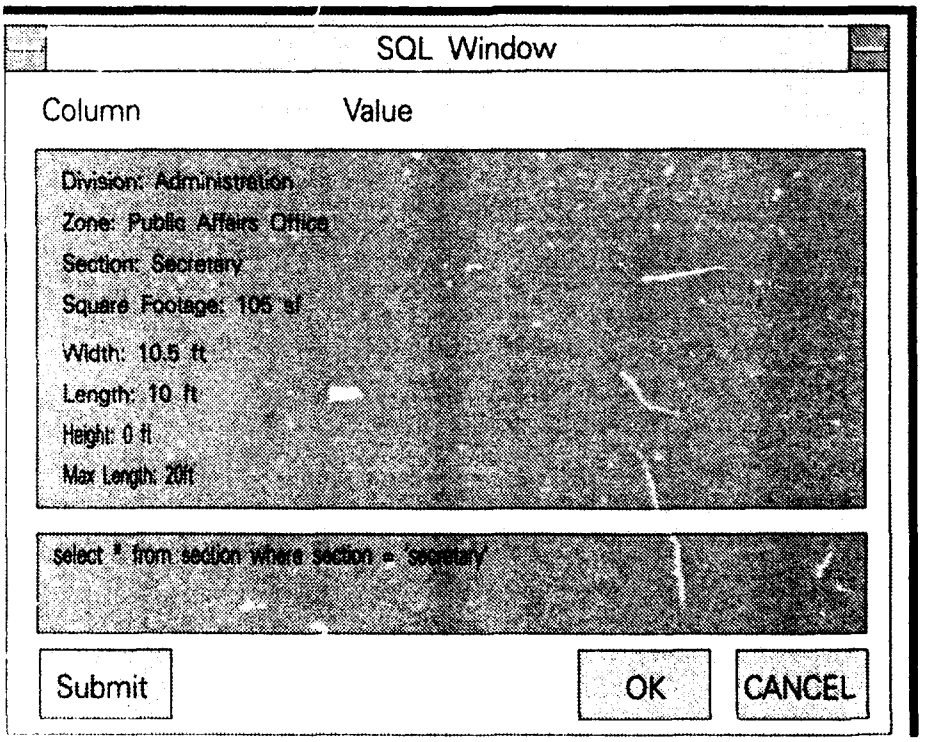

Figure 4. Information Review Window.

5 CONCLUSIONS AND RECOMMENDATIONS

MicroStation PC Version 4.0, MDL, and Oracle's RDBMS together have proven to be an excellent development platform for automating conceptual design stages of a project. While the other platforms and concept analysis tools evaluated met certain qualifications, MicroStation's platform is the only one that has a CAD engine, a shared database, and allows development of different custom applications. MicroStation's PC CAD engine is compatible with all Intergraph software products used extensively in the Corps of Engineers. The MicroStation Development Language enables complete user customization by allowing access to the core MicroStation commands. Also, the Oracle RDBMS provides the ability to associate graphic and nongraphic information in a shared environment.

It is recommended that researchers continue to develop automated concept analysis tools using the MicroStation 4.0 platform. These tools could include building code examinations, quantity takeoffs, and facility management tools such as inventory, space and personnel allocation, and forecasting. It is also recommended that these tools be pilot-tested at the USACE districts and divisions to determine the need for future development.

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